

MONTHLY WEATHER REVIEW

JAMES E. CASKEY, JR., Editor

Volume 84
Number 3

MARCH 1956

Closed May 15, 1956
Issued June 15, 1956

EXAMPLES OF THE MEAN THREE-DIMENSIONAL WIND CIRCULATION OVER THE TROPICAL NORTH PACIFIC OCEAN

GORDON A. DEAN

Institute of Geophysics, University of California¹

[Manuscript received February 13, 1956; revised March 29, 1956]

ABSTRACT

Two extreme climatological contrasts in the 1954 mean monthly wind circulation over the tropical North Pacific Ocean are presented in the form of cross sections and horizontal analyses. The wind field is shown on cross sections near 165° E. from 5° to 35° N. latitude. The horizontal variations of the wind are shown at 10,000-foot intervals throughout the troposphere and lower stratosphere. Twenty-seven figures are presented.

1. INTRODUCTION

Until recently, the lack of upper air data in the Tropics has prevented climatologists from preparing maps depicting mean high-level circulation patterns over most of the tropical North Pacific Ocean. In an attempt to correct the lack, as far as this is possible with recent RAWIN data, one phase of the work conducted in tropical meteorology at the Oahu Research Center has been the drawing of detailed analyses of mean monthly winds for various atmospheric levels over the Marshall Islands (Korshover [1]). Although limited data have confined Korshover's work to the atomic weapons testing periods consisting of GREENHOUSE (spring 1951), IVY (fall 1952), and CASTLE (spring 1954), study of the analyses has suggested that *two*, significantly different, mean wind flow patterns regularly occur over the Marshall Islands. Consequently, it is the purpose of this paper to describe these patterns more fully by extending the three-dimensional analysis of the mean wind flow patterns to the entire tropical North Pacific Ocean area.

2. THE TWO MEAN WIND FLOW PATTERNS

The first mean wind flow pattern illustrated (figs. 8-17) is derived from winds prevailing during the month of February 1954. This was a "high index" period and the horizontal analyses are believed to be typical at each level of the mean wind circulation over the tropical North Pacific Ocean area during high zonal index in temperate latitudes. Daily analyses show that the synoptic flow pattern in the middle and high troposphere through the month was essentially zonal and strong in speed.

The second mean wind flow pattern illustrated (figs. 18-27) is based on winds observed during the period April 16 through May 15, 1954. For this interval of time the mean horizontal analyses are believed to be typical at each level studied of the mean wind circulation during a "low index" period. That the mean wind analyses are representative of high and low index situations can be checked by the striking similarity of the climatological maps to the daily synoptic maps for the same periods as analyzed by the weather personnel on OPERATION CASTLE. In other words, the daily departure of the synoptic field of motion, from the mean, for both periods was very small.

The meager evidence from years before 1954 (almost

¹ The research work in this paper has been made possible by support of the Geophysics Research Directorate of the Air Force Cambridge Research Center under Contract No. AF19(604)-546.

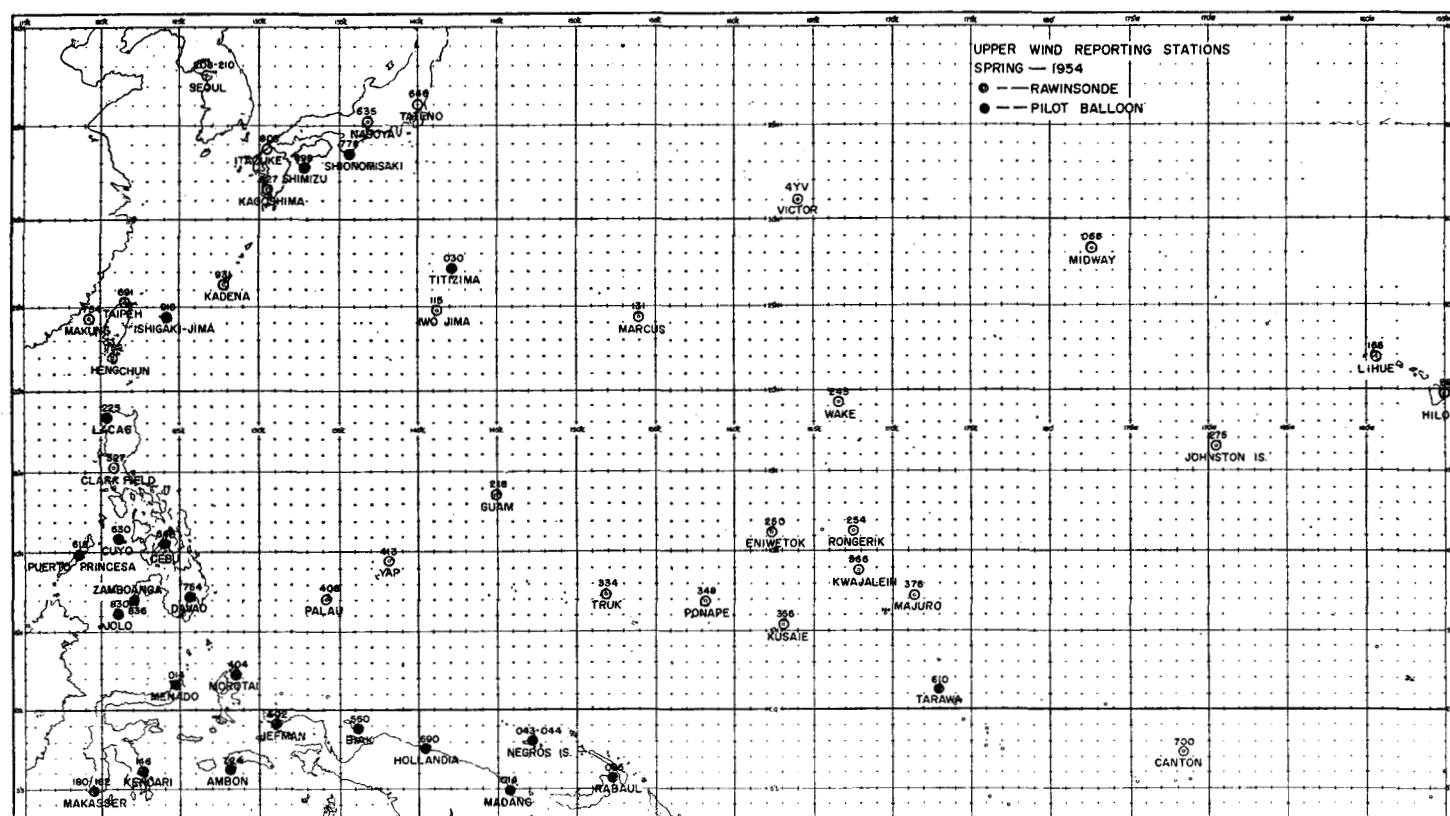


FIGURE 1.—Upper-air observing network in the Central Pacific during spring 1954.

TABLE 1.—Pacific upper-wind stations, types of wind finding equipment, and times of observation

Station No.	Station name	Type of wind finding equipment**	Time of observation (GMT)	Station No.	Station name	Type of wind finding equipment**	Time of observation (GMT)
<i>Block 91</i>				<i>Block 47</i>			
066	Midway	R	03, 09, 15, 21	208	Seoul	R	03, 09, 15, 21
115	Iwo Jima	R	03, 09, 15, 21	635	Nagoya	R	03, 09, 15, 21
131	Marcus	P	03, 09, 15, 21	646	Tateno	R	03, 15
47V	Victor	R	03, 09, 15, 21	778	Shionomisaki	R	03, 09, 15, 21
185	Lihue	R	03, 09-P, 15, 21-P	808	Itazuke	R	03, 09, 15, 21
218	Guam	R	03, 09, 15, 21	827	Kagoshima	R	03, 09, 15, 21
248	Wake	R	03, 09, 15, 21	898	Shimizu	P	03, 09, 15, 21
250*	Eniwetok	R	03, 09, 15, 21	931	Okinawa	R	03, 09, 15, 21
254	Rongerik	R	03, 09, 15, 21				
275	Johnston	R	03, 09, 15, 21	<i>Block 94</i>			
285	Hilo	R	03, 09-P, 15, 21-P	014	Madang	P	04, 10, 16, 22
334	Truk	R	03, 15-P	085	Rabaul	P	04, 10, 16, 22
348*	Ponape	R	03, 09, 15, 21				
356*	Kusaie	R	03, 09, 15, 21	<i>Block 97</i>			
366*	Kwajalein	R	03, 09, 15, 21	014	Menado	P	05, 11, 23
376*	Majuro	R	03, 09, 15, 21	146	Kendari	P	05, 11, 23
408	Palau	R	03, 15-P	180	Makassar	P	05, 11, 23
413	Yap	R	03, 15-P	404	Morital	P	05, 11, 23
530	Nauru	CL	00, 06	502	Jefman	P	02, 08, 23
533	Ocean	CL	00, 06, 12, 18	560	Biak	P	03, 08, 22
610	Tarawa	P	05, 11, 17, 23	690	Hollandia	P	02, 08, 22
623	Beru	CL	00, 06, 18	724	Ambon	P	05, 11, 23
487	Fanning	CL	00, 06, 18				
490	Christmas	CL	00, 06, 18	<i>Block 98</i>			
700	Canton	R	03, 09, 15, 21	223	Laoag	P	03, 15
705	Gardner	CL	00, 06, 18	327	Clark Field	R	03, 09, 15, 21
10	Hull	CL	00, 06, 18	618	Puerto Princesa	P	03, 15, 21
<i>Block 46</i>				630	Cuyo	P	03, 21
697	Taipeh	R	03, 09, 15, 21	645	Cebu	P	03, 15
734	Makung	R	03, 09, 15, 21	754	Davao	P	03, 15
752	Hengchun	R	03, 09, 15, 21	830	Jolo	P	03, 09
				836	Zamboanga	P	03, 15, 21

*Occasionally 3-hourly observations are included in addition to the required 6-hourly observations.

**R=Rawinsonde. P=Pilot balloon. CL=Low-level cloud direction.

TABLE 2.—Number of wind observations at each wind analysis level

Station	Level (ft.)									
	2,000	10,000	20,000	30,000	40,000	50,000	60,000	65,000	70,000	80,000
FEBRUARY 1-28, 1954										
Block 91										
4YV-----	80	79	50	17						
066-----	108	110	106	88	64	41	24	20	17	11
115-----	90	69	53	41	28	18	10	9	10	9
131-----	106	106	107	91	71	38	18	8		
165-----	97	74	64	47	34	23	10	10		
218-----	111	111	108	106	105	89	49	45	39	26
245-----	108	110	107	98	79	44	17	13		
250-----	123	123	122	123	123	122	94	92	86	64
254-----	82	87	85	85	85	79	56	51	51	42
275-----	112	110	109	108	100	89	58	49	45	37
285-----	90	70	61	48	37	27				
334-----	54	47	30	27	26	22	16	15	16	
348-----	106	106	108	108	108	107	71	69	69	63
356-----	101	108	107	109	109	107	75	66	63	57
366-----	117	108	81	71	66	58	48	41	38	29
376-----	107	109	110	108	107	104	93	91	89	85
408-----	52	42	23	10	7					
413-----	47	41	32	26	26	22	14	15	11	
610-----	102	23								
700-----	112	105	77	63	62	49	26	21	13	
Block 46										
697-----	59	53	47	38	22					
734-----	73	65	59	37						
752-----	73	71	64	61	62	41				
Block 47										
208-----	69	71	64	56	41	29				
635-----	101	82	61	49	29	21				
646-----	47	48	48	44	34	19				
778-----	100	90	72	40						
808-----	94	60	51	42	26					
827-----	91	64	57	19						
898-----	89	62	22							
931-----	86	55	39	24						
Block 94										
014-----	43	31								
044-----	12									
085-----	38									
Block 97										
014-----	38									
146-----	44	23								
180-----	44	19								
404-----	21									
502-----	20									
560-----	44									
690-----	27									
724-----	55	34								
Block 98										
223-----	41	40	24	16						
327-----	88	76	60	51	48	38				
618-----	33	26								
630-----	36	30								
645-----	47	34								
754-----	47	34	23	17						
830-----	47	33								
898-----	43	39	22							
APRIL 16-MAY 15, 1954										
Block 91										
4YV-----	103	95	84	64	46	32	21			
066-----	118	111	106	102	85	50	27	22	17	40
115-----	94	104	104	104	104	96	62	57	50	35
131-----	115	114	111	103	99	86	65	59	50	
165-----	115	78	67	63	60	33	19	17	15	
218-----	114	114	114	110	105	98	63	58	53	35
245-----	115	117	116	116	111	95	66	51	43	16
250-----	146	144	142	140	140	137	109	99	91	81
275-----	117	117	117	117	114	72	39	30	27	26
285-----	110	83	71	60	53	36	24			
334-----	57	54	32	22	20	18	13	14	12	
348-----	130	130	130	130	129	129	108	97	94	89
356-----	126	129	128	129	129	113	84	76	74	72
366-----	139	139	139	137	136	109	58	51	48	34
376-----	125	128	128	127	126	121	86	88	86	77
438-----	58	50	41	30	26	23	19	18		
413-----	57	43	30	25	24	21				
610-----	73	32								
700-----	120	114	97	83	73	58	33	24	19	
Block 46										
697-----	49									
752-----	79	78	76	78	75	67				
Block 47										
208-----	89	87	89	81	56	25				
635-----	102	90	72	53	43					
646-----	55	56	54	52	41	26				
778-----	99	83	58	46	24					
808-----	106	101	95	67	46	23				
827-----	92	75	55	27						
898-----	80	55								
931-----	108	107	104	98	95	64				
Block 94										
014-----	39	23								
085-----	46	25								
Block 97										
014-----	42	26								
146-----	24	18								
180-----	53	34								
404-----	26	22								
502-----	42	29								
560-----	37	20								
590-----	65	21								
724-----	37	21								
Block 98										
223-----	49	46	31	18						
327-----	114	105	83	62	59	57				
618-----	25	18								
630-----	47	30								
645-----	48	42	33							
754-----	43	31	19							
830-----	18	14								
898-----	41	39	29							

entirely confined to periods during which tests were made in the Marshalls) strongly suggests that, if a long series of observations were available, the two situations presented here as "high" and "low" index would be typical in the tropical Pacific of the months February and May; that is, that anticyclogenesis aloft in the Central Pacific culminates in February, cyclogenesis in May. However, the voluminous data upon which a firm statement about seasonal trends could be made

have yet to be collected. For this reason, the terms "high" and "low" index, as used here, are purely qualitative and descriptive, and no attempt is made to disentangle the synoptic from the seasonal aspects of the two situations. In the high-index situation, the jet stream is strong in speed, the subtropical anticyclones aloft lie close to the equator, and the entire flow pattern is strongly zonal. In the low-index situation the jet stream is weak, the subtropical anticyclones aloft are centered outside

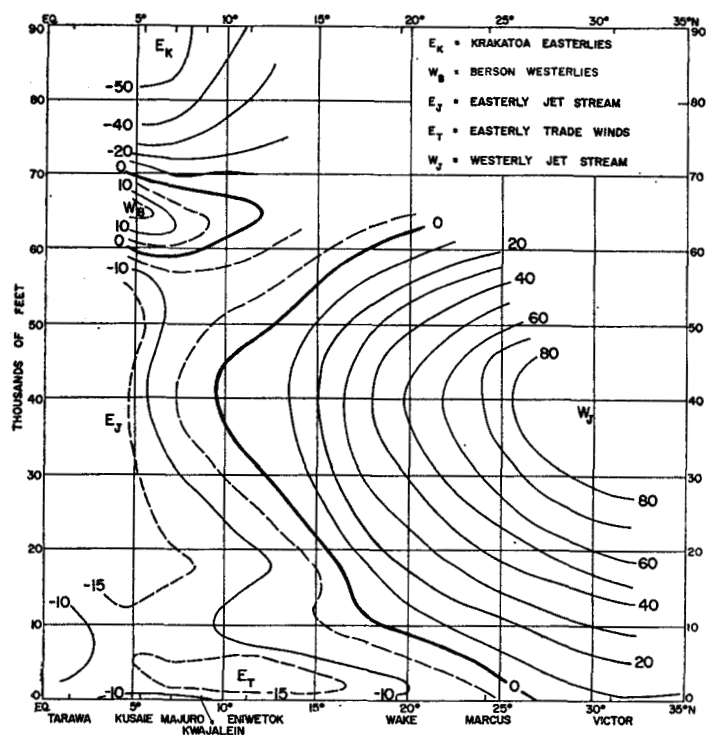


FIGURE 2.—Mean zonal component of the wind in knots near 167° E., February 1954.

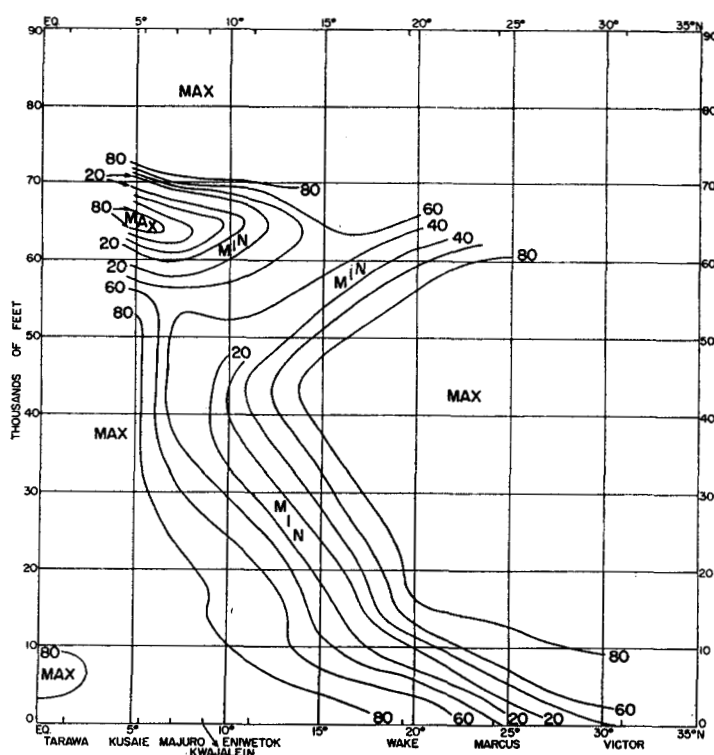


FIGURE 4.—Steadiness of the wind in percent near 167° E., February 1954.

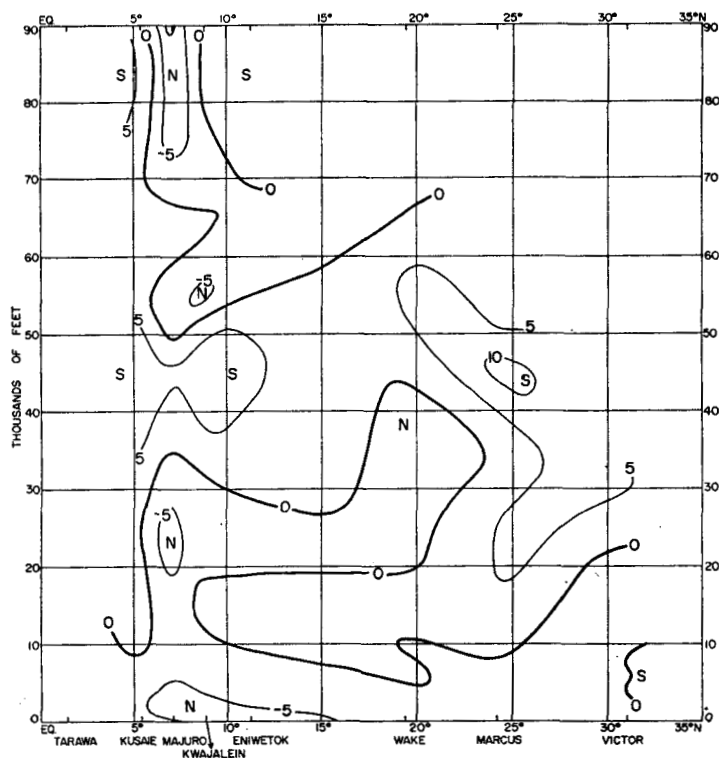


FIGURE 3.—Mean meridional component of the wind in knots near 167° E., February 1954.

the Tropics, and the wind pattern aloft shows large meridional air movement associated with upper-level cyclogenesis. The maps presented here illustrate the low-latitude concomitants of these situations. The difficult question of the part played by seasonal variation has to be treated at greater length in future publications.

3. ANALYSIS METHOD

The area of analysis extended from Hawaii to the coast of Asia in the east-west direction and from 0° to 35° N. in the north-south direction. The lowest level of analysis selected was 2,000 feet; winds at that level are not affected by possible orographic disturbances due to low-lying atolls. Good evidence of profound orographic effects is seen near the borders of the maps, such as in the Philippines, Formosa, and Japan. Here, the 2,000- and even 10,000-foot winds reveal large departures from a consistently smooth flow.

Above 2,000 feet, and starting with the 10,000-foot chart, the wind analyses have been carried out at 10,000-foot intervals to 80,000 feet (figs. 8-27). Because the wind structure immediately above the tropopause is complex, an additional chart at 65,000 feet has been included.

All upper wind data were obtained from teletypewriter collectives received at various stations in the Pacific. The upper wind reporting stations, their type of wind-finding equipment, and their scheduled times of observa-

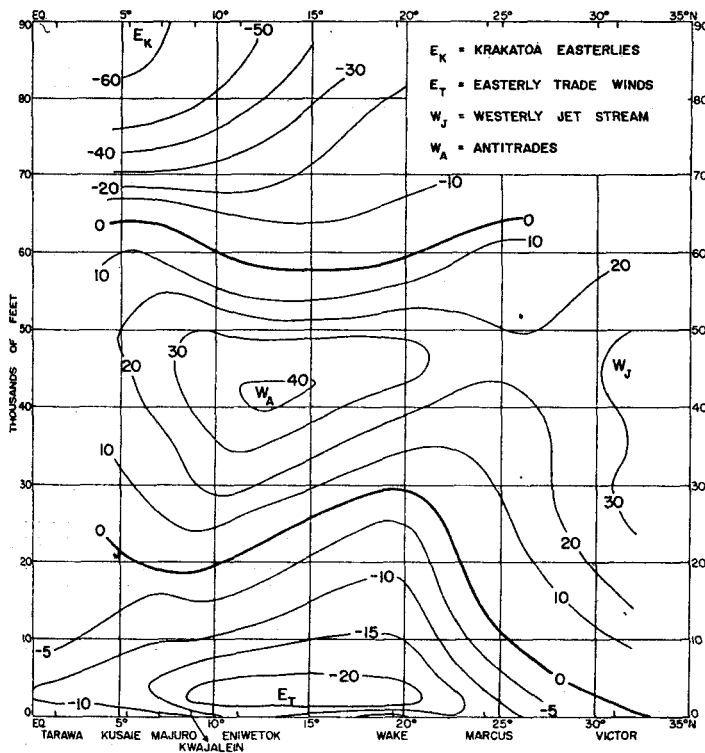


FIGURE 5.—Mean zonal component of the wind in knots near 167° E., April 16–May 15, 1954.

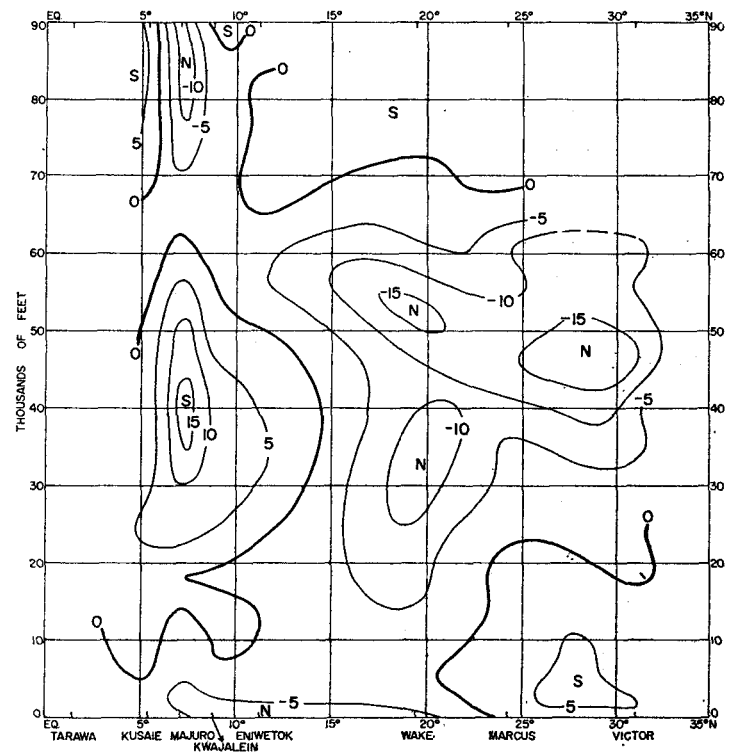


FIGURE 6.—Mean meridional component of the wind in knots near 167° E., April 16–May 15, 1954.

tion are listed in table 1 for reference. The geographic distribution of the stations is shown in figure 1. Table 2 contains the number of wind observations that were used to arrive at the mean resultant wind value for each analysis level.

The streamline analyses have been performed by the isogon method (Palmer and others [2]). The speed lines have been drawn for 10-knot intervals, and occasionally where gradients were weak, a 5-knot interval was used.

The three-dimensional aspect of the wind circulation shown on each horizontal wind chart may be enhanced through the use of a wind cross-section drawn for 167° E. The \bar{u} and \bar{v} components of the wind and the wind steadiness ($\bar{S} = \frac{|\bar{V}|}{\bar{C}}$ where S is the steadiness, $|\bar{V}|$ is the

mean vector speed, and \bar{C} is the mean wind speed irrespective of wind direction) are presented in figures 2–7. The names of all large-scale wind systems have been identified at their centers with appropriate symbols (Palmer [2], [3]).

4. COMMENTS ON THE MAPS

The following points deserve special emphasis:

1. No other tropical region in the world contains so dense a RAWIN observational network as that now in existence in the Central Pacific.

2. The wind circulations presented herein were selected

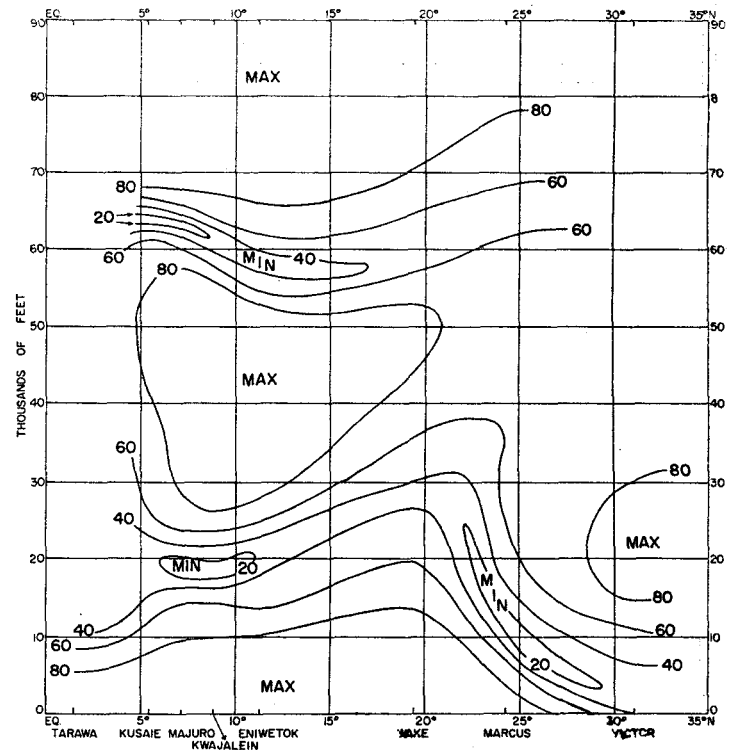


FIGURE 7.—Steadiness of the wind in percent near 167° E., April 16–May 15, 1954.

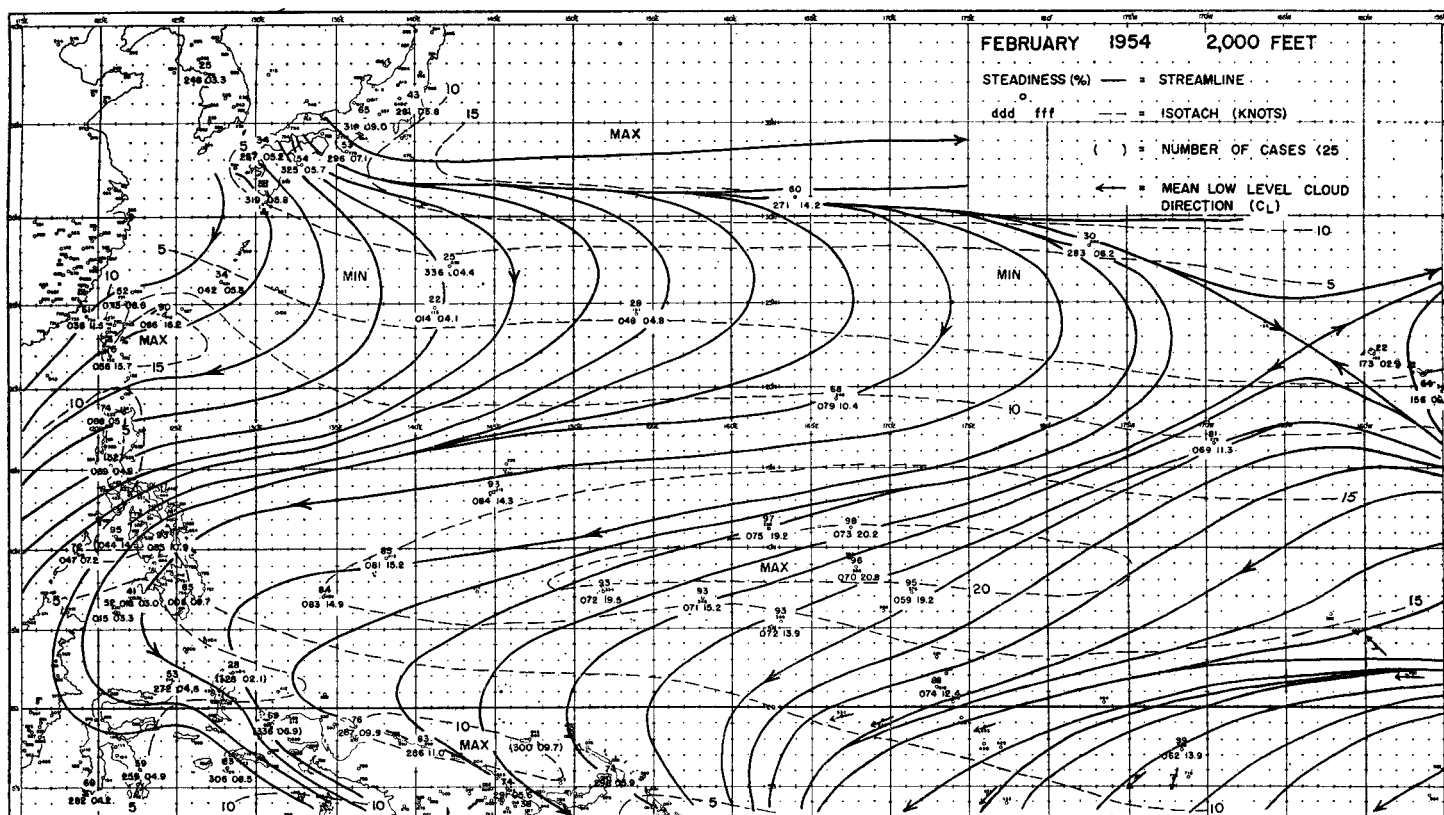


FIGURE 8.—The field of motion at 2,000 feet, February 1954.

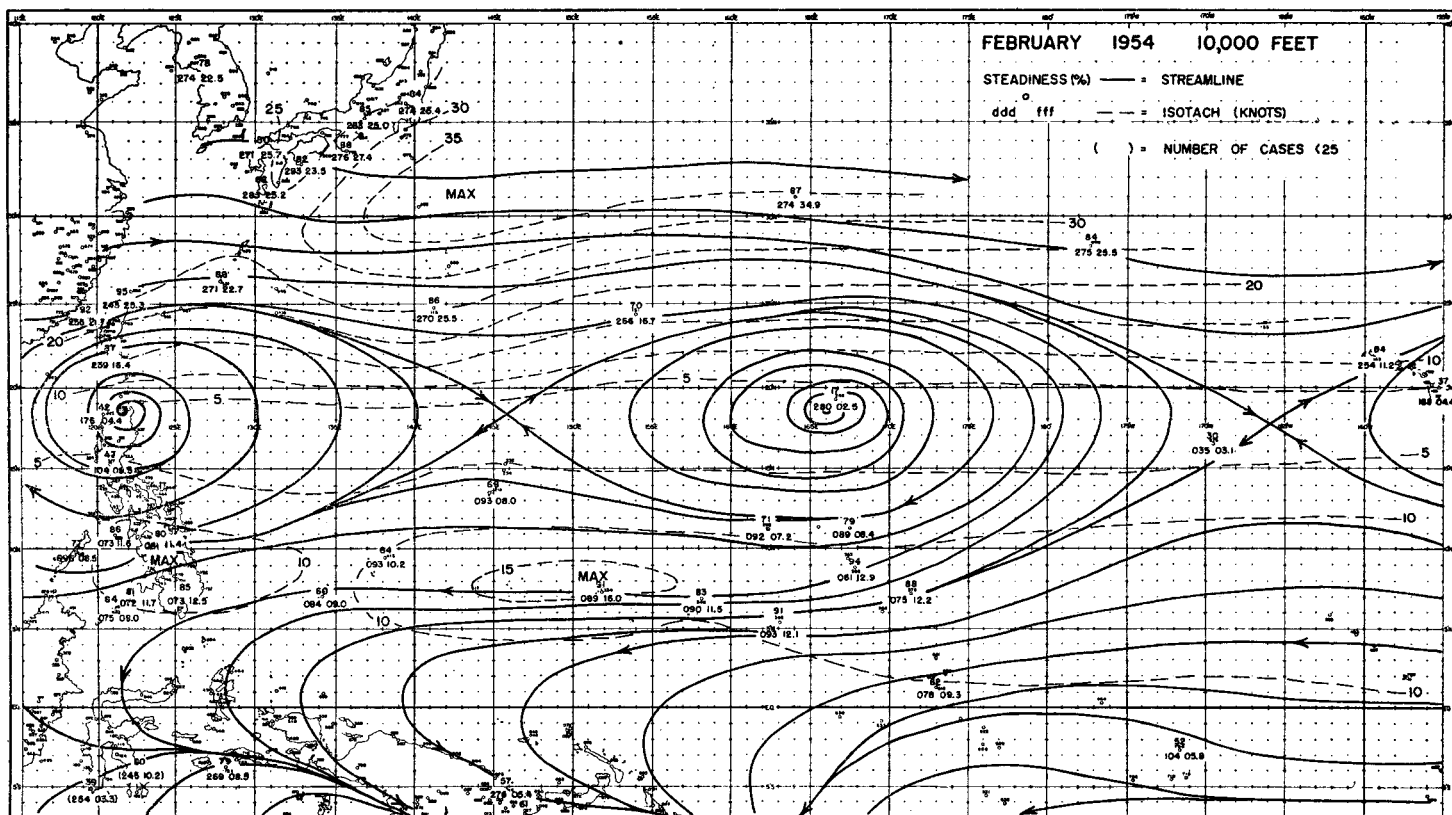


FIGURE 9.—The field of motion at 10,000 feet, February 1954.

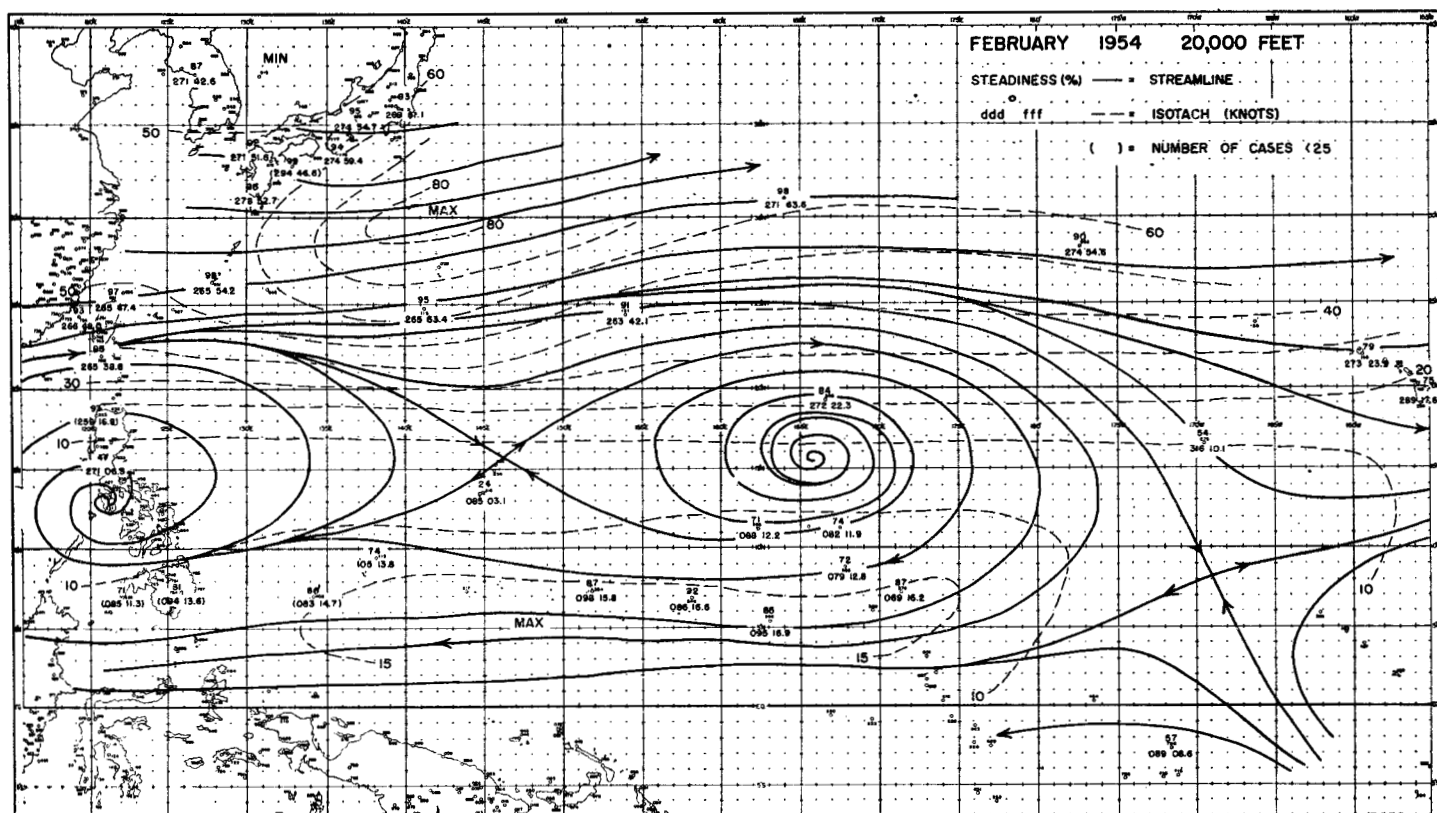


FIGURE 10.—The field of motion at 20,000 feet, February 1954.

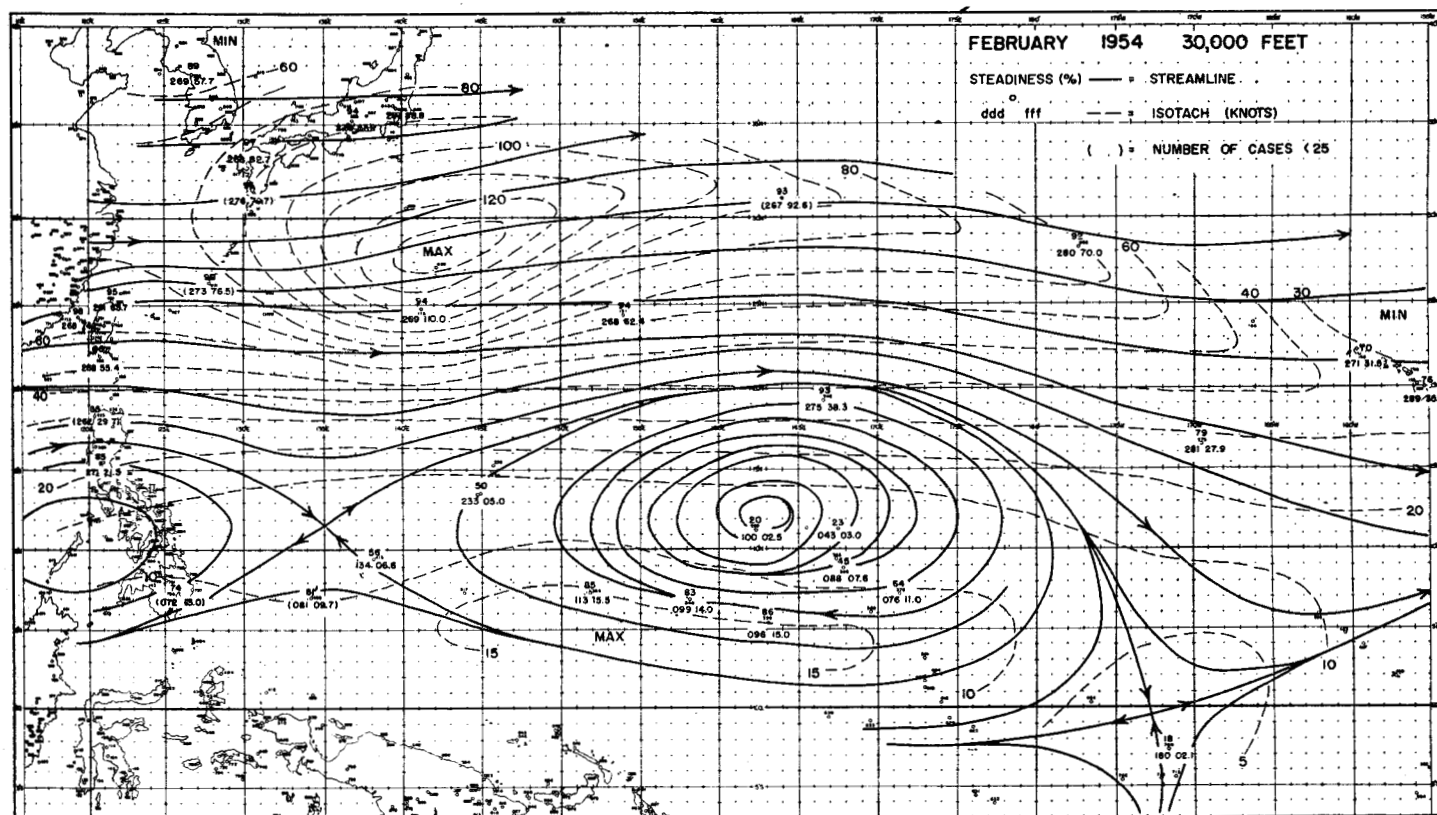


FIGURE 11.—The field of motion at 30,000 feet, February 1954.

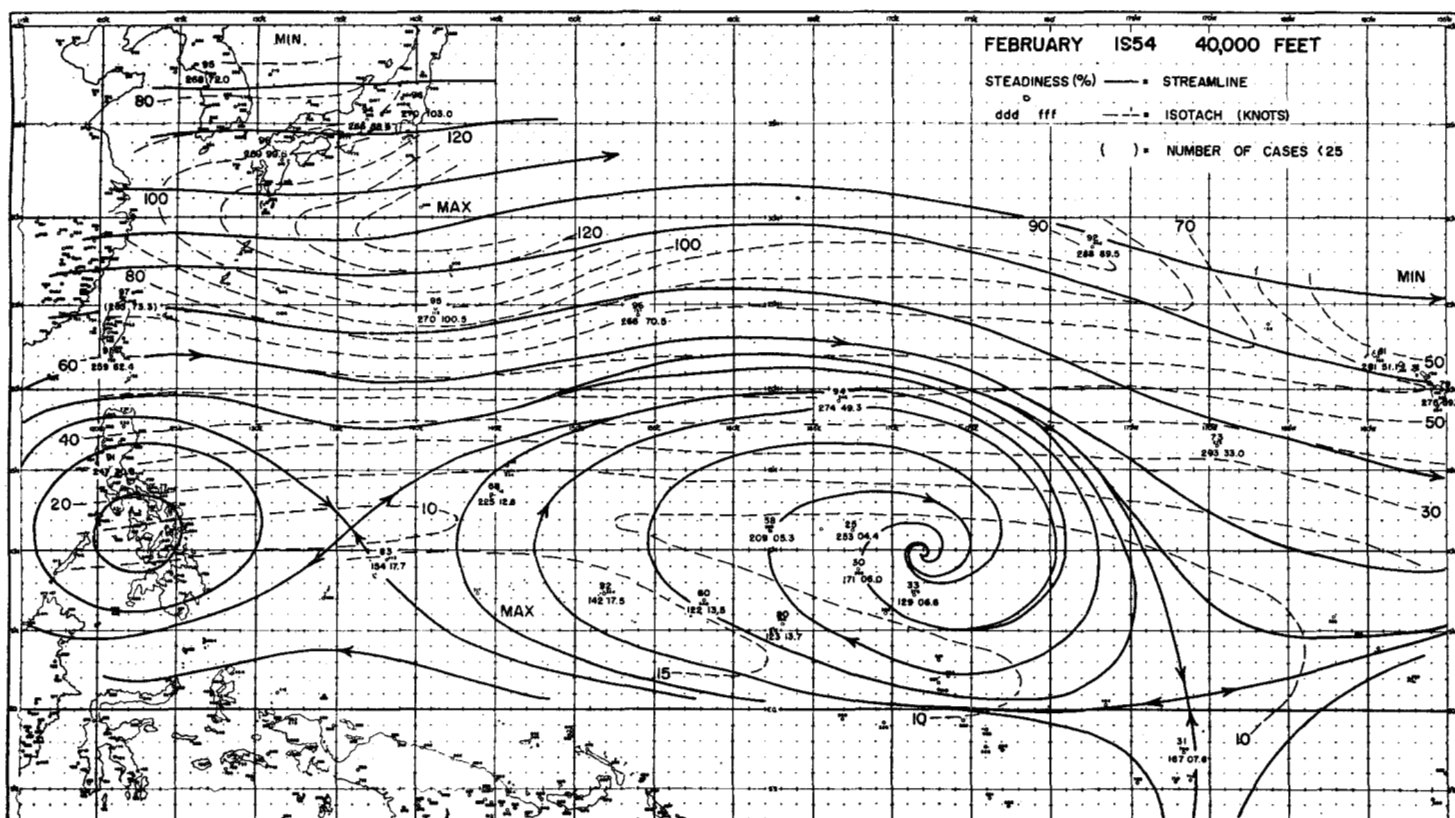


FIGURE 12.—The field of motion at 40,000 feet, February 1954.

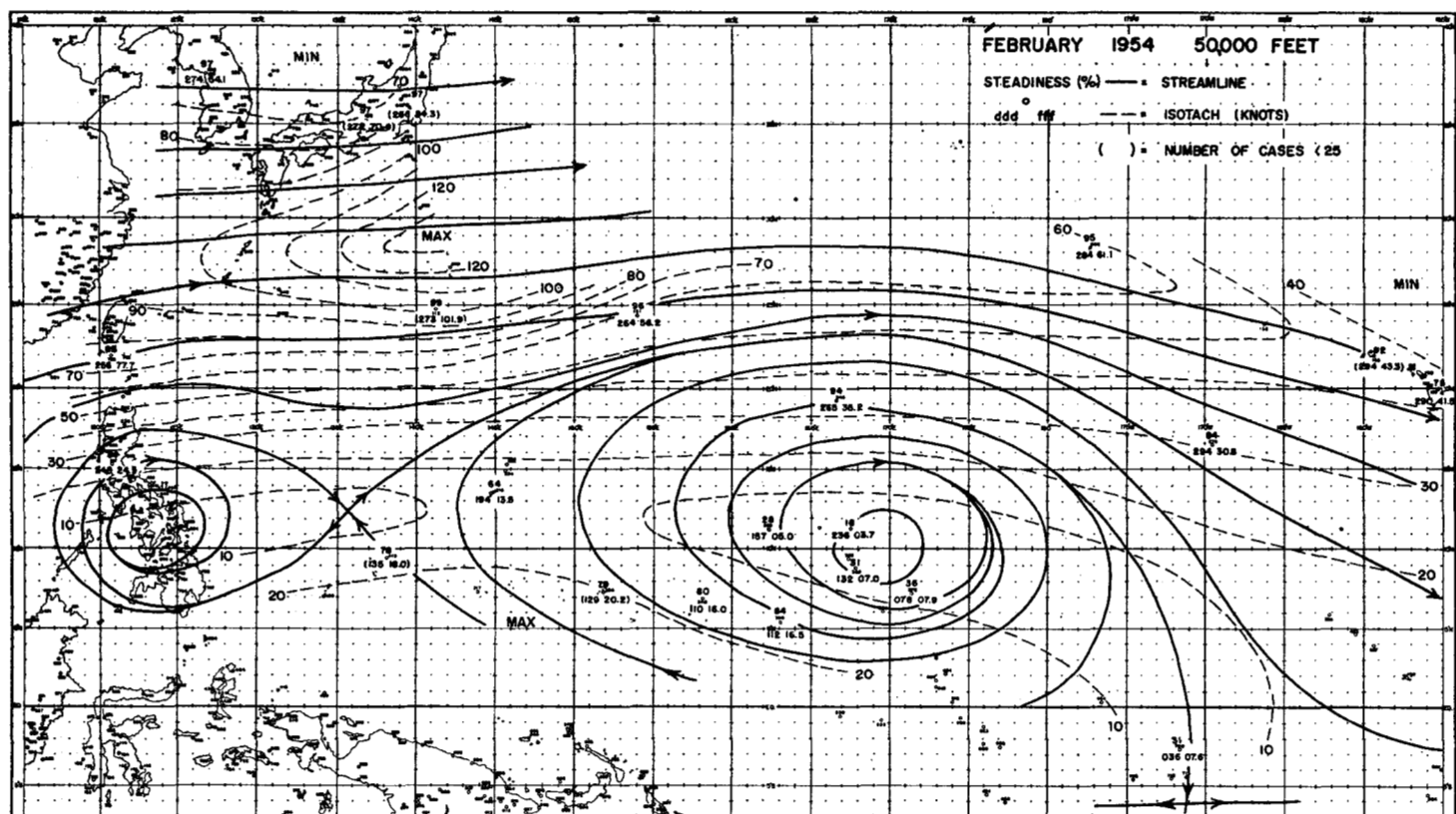


FIGURE 13.—The field of motion at 50,000 feet, February 1954.

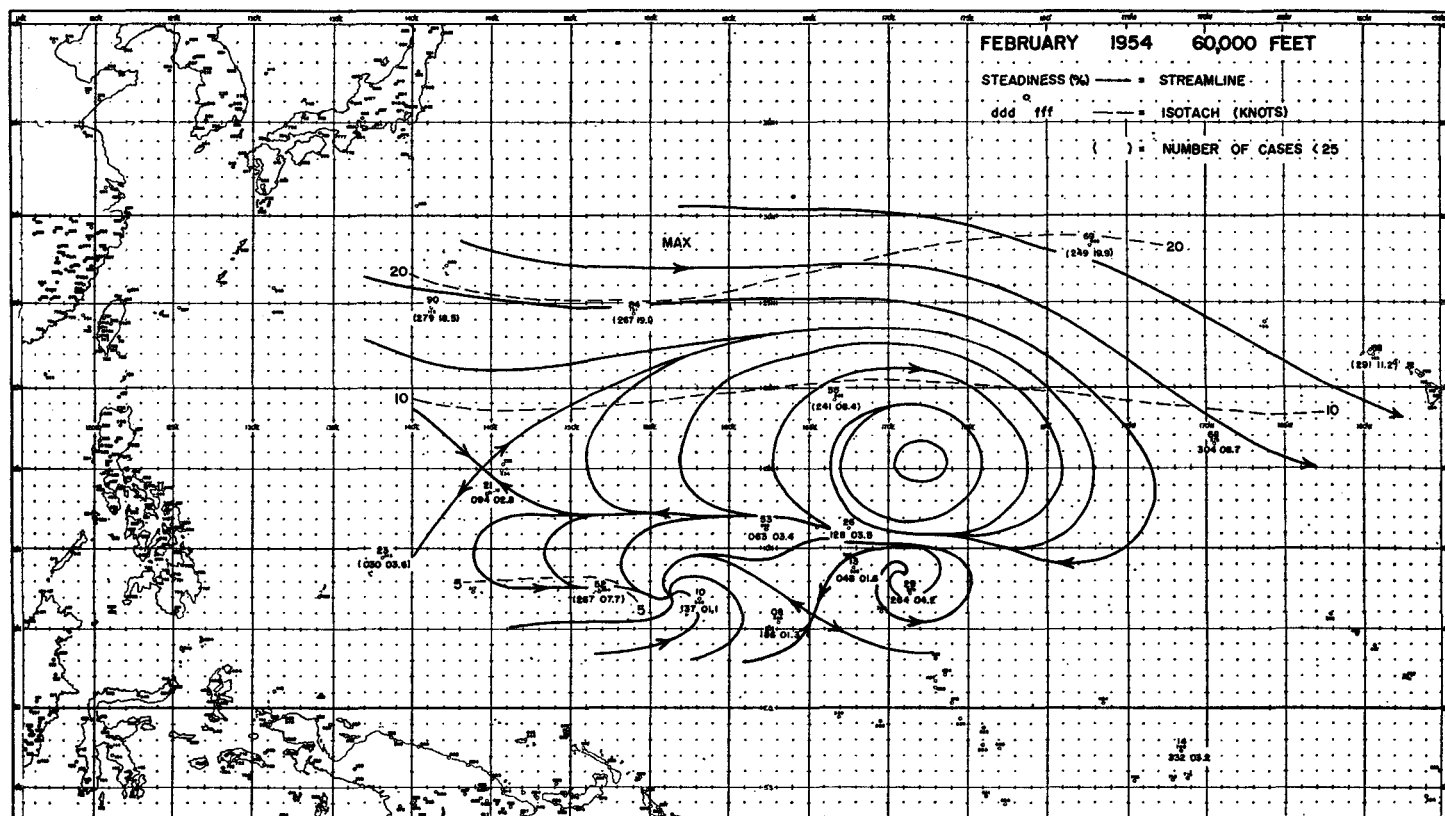


FIGURE 14.—The field of motion at 60,000 feet, February 1954.

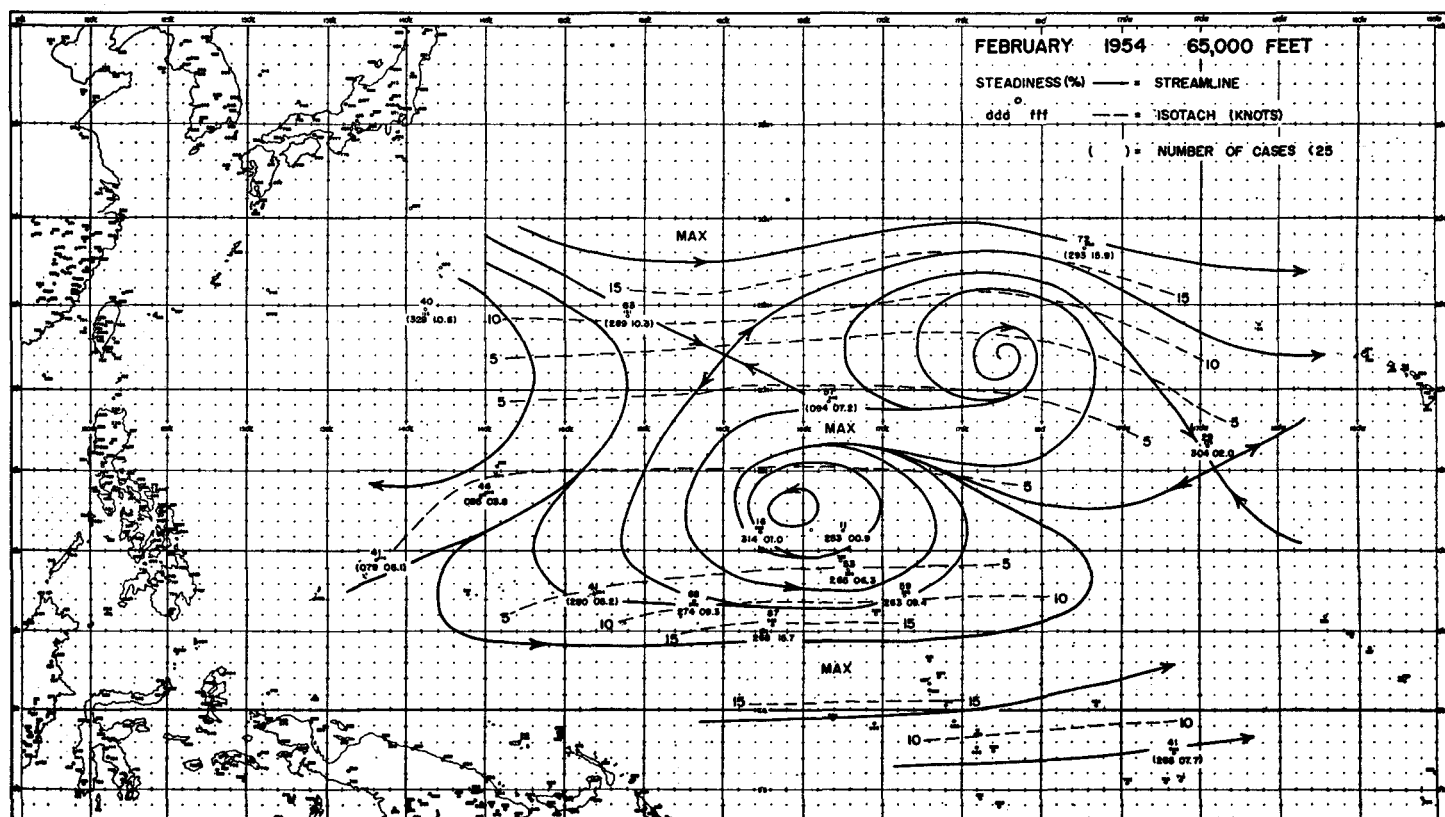


FIGURE 15.—The field of motion at 65,000 feet, February 1954.

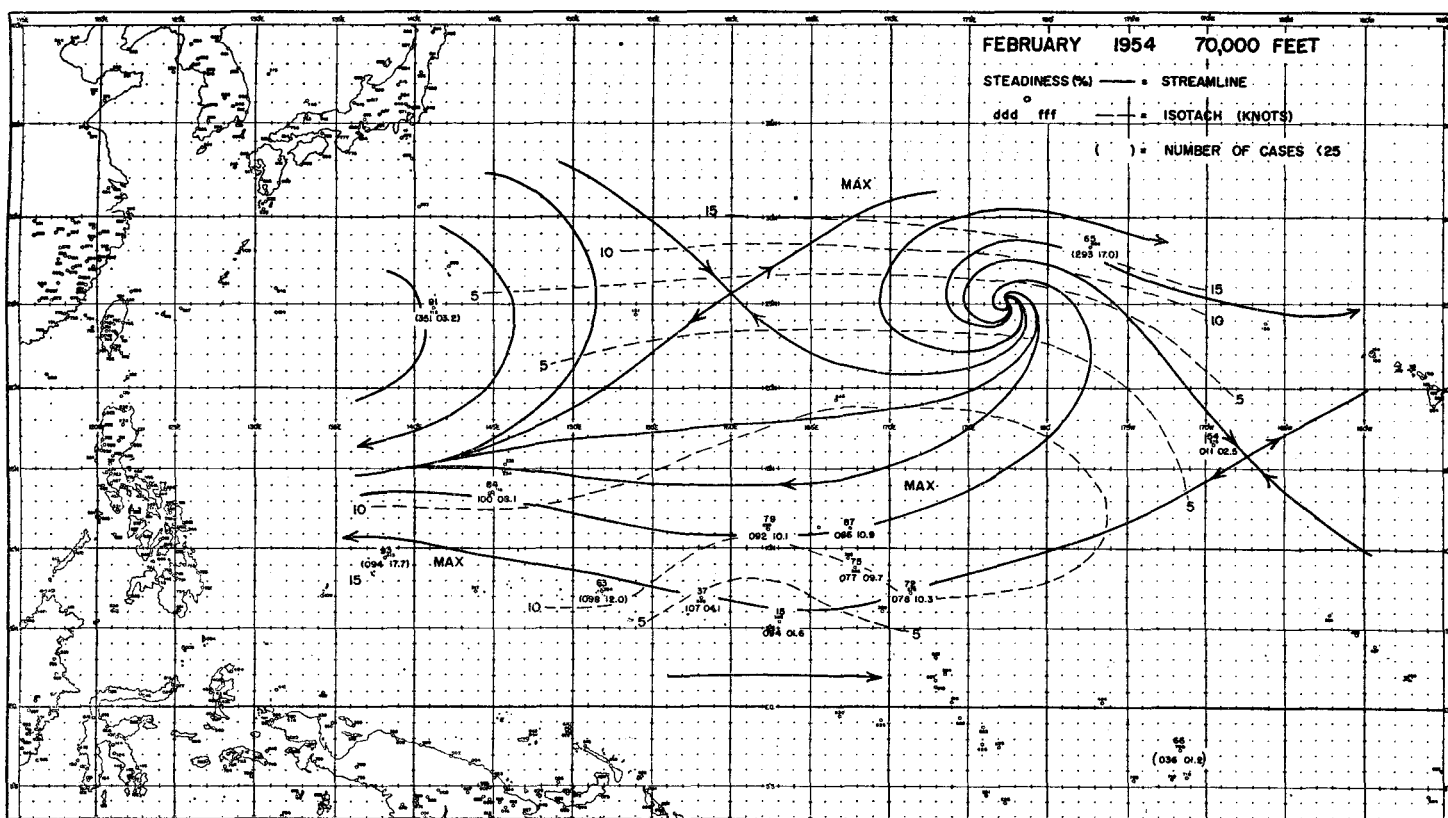


FIGURE 16.—The field of motion at 70,000 feet, February 1954.

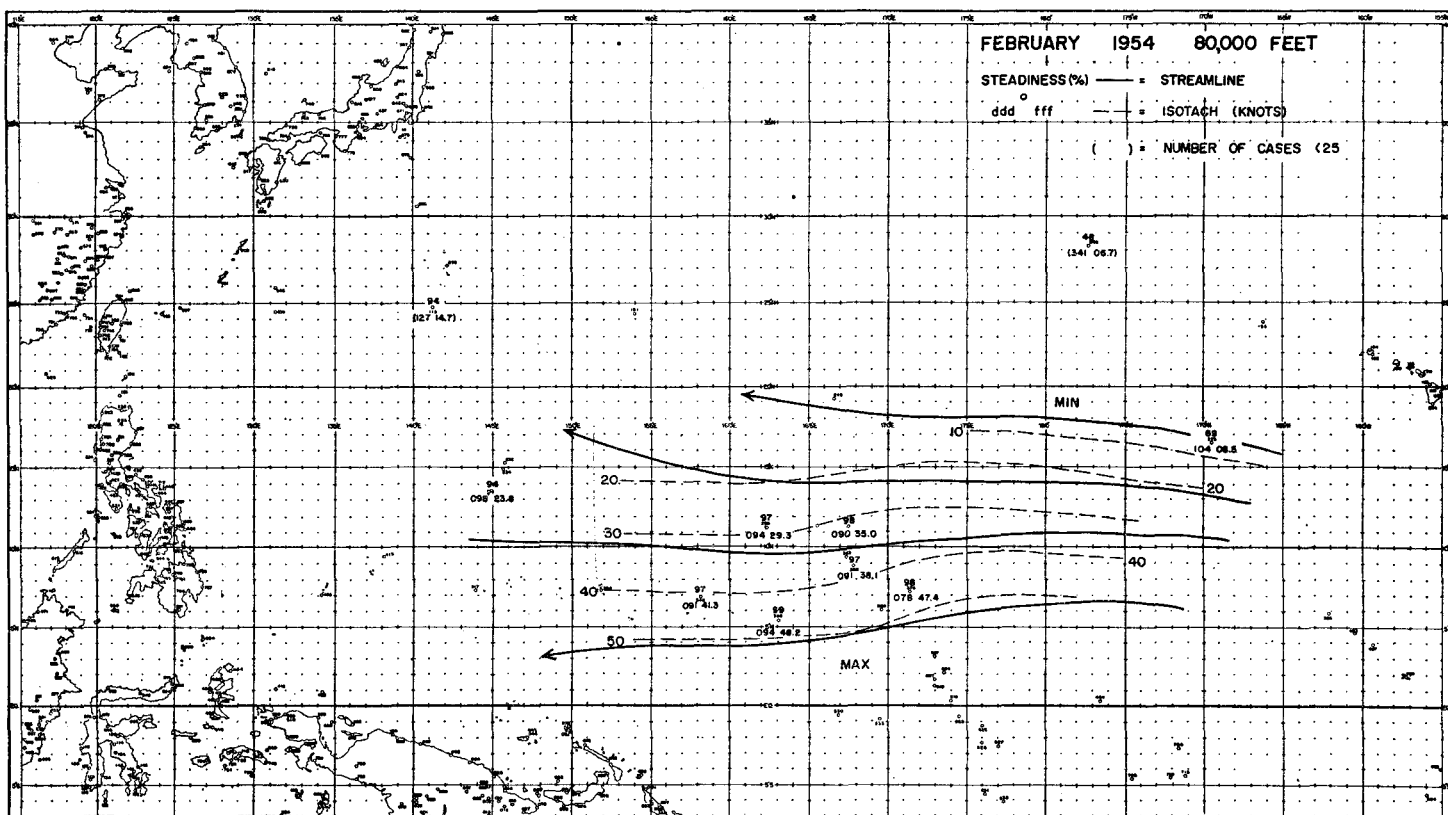


FIGURE 17.—The field of motion at 80,000 feet, February 1954.

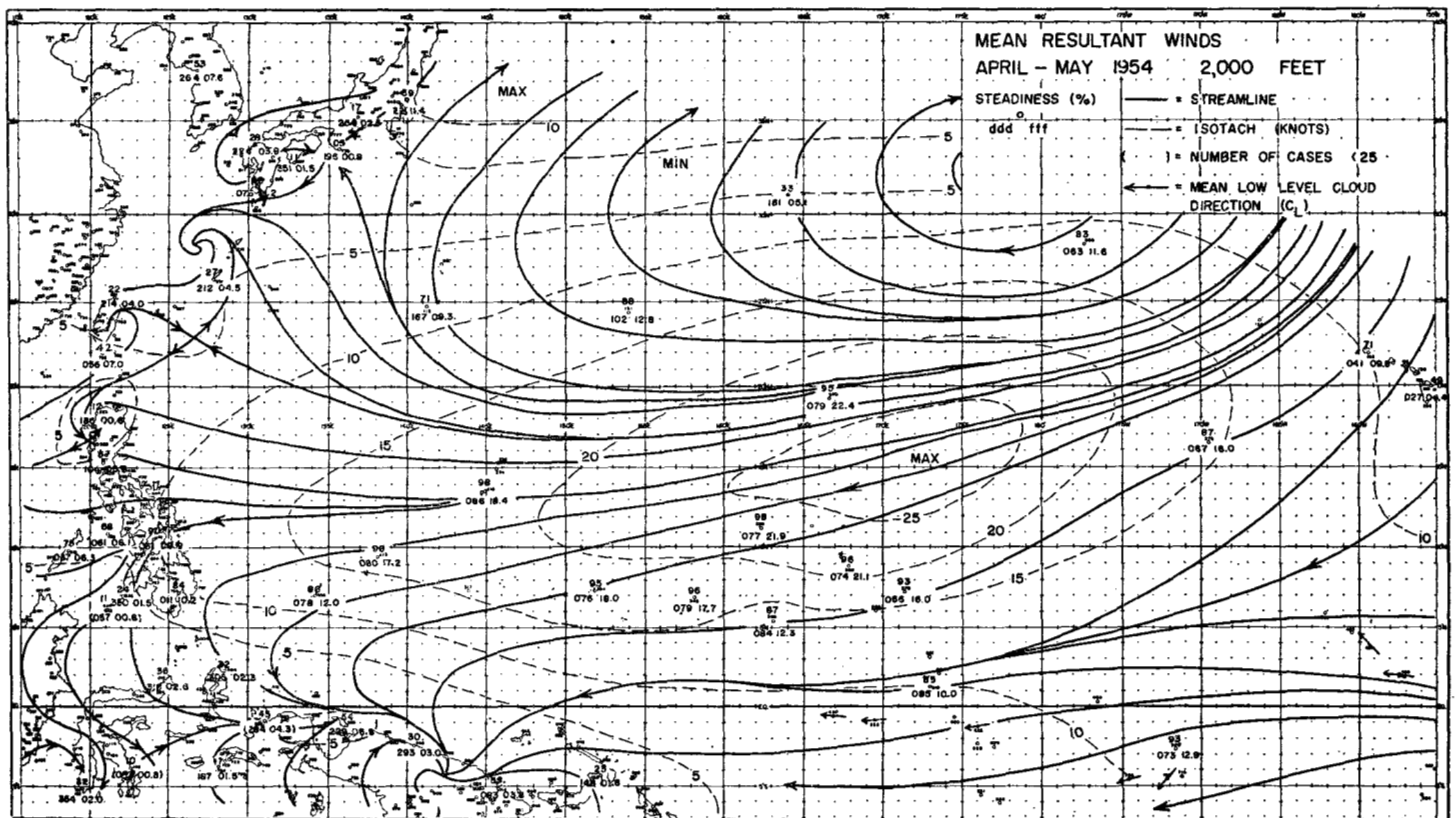


FIGURE 18.—The field of motion at 2,000 feet, April 16-May 15, 1954.

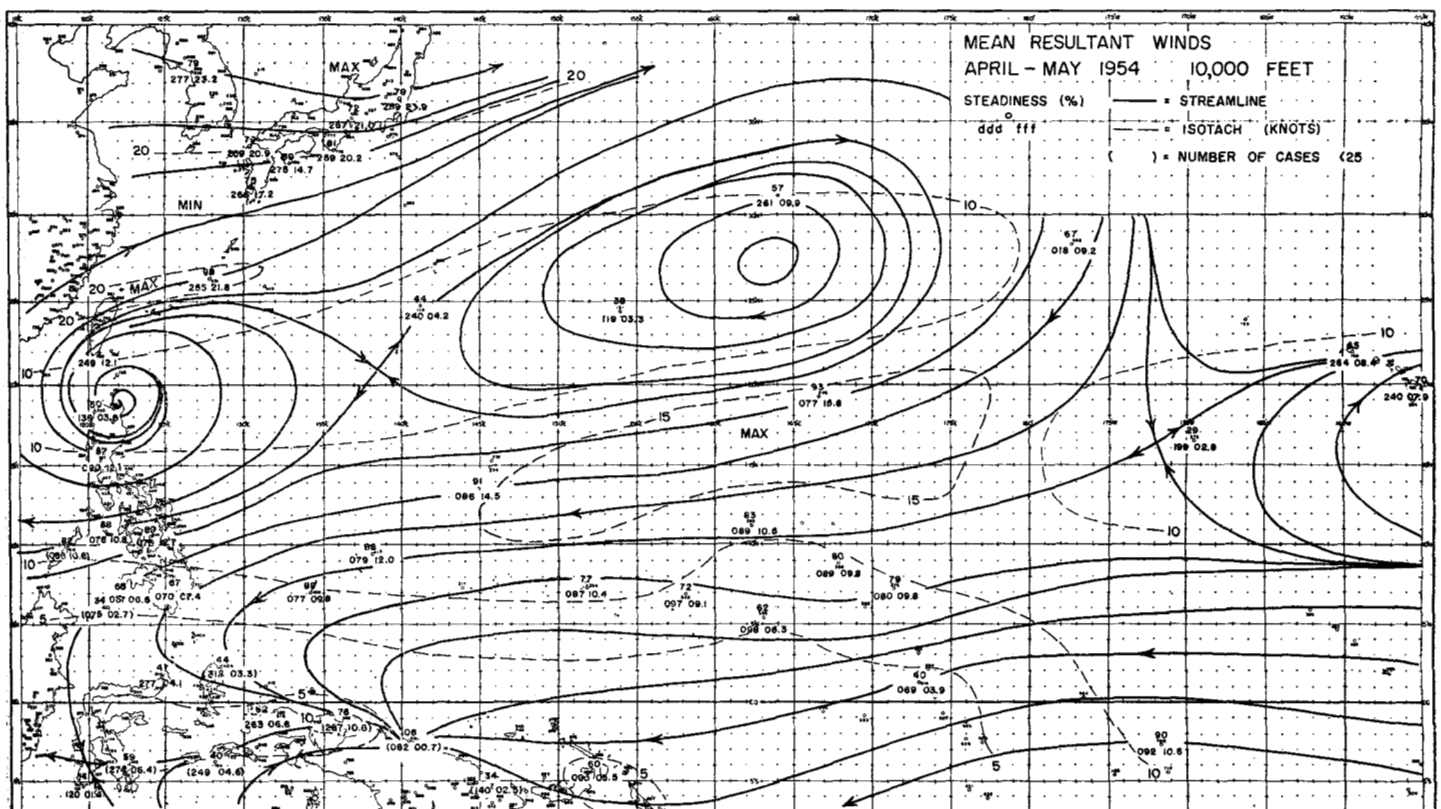


FIGURE 19.—The field of motion at 10,000 feet, April 16-May 15, 1954.

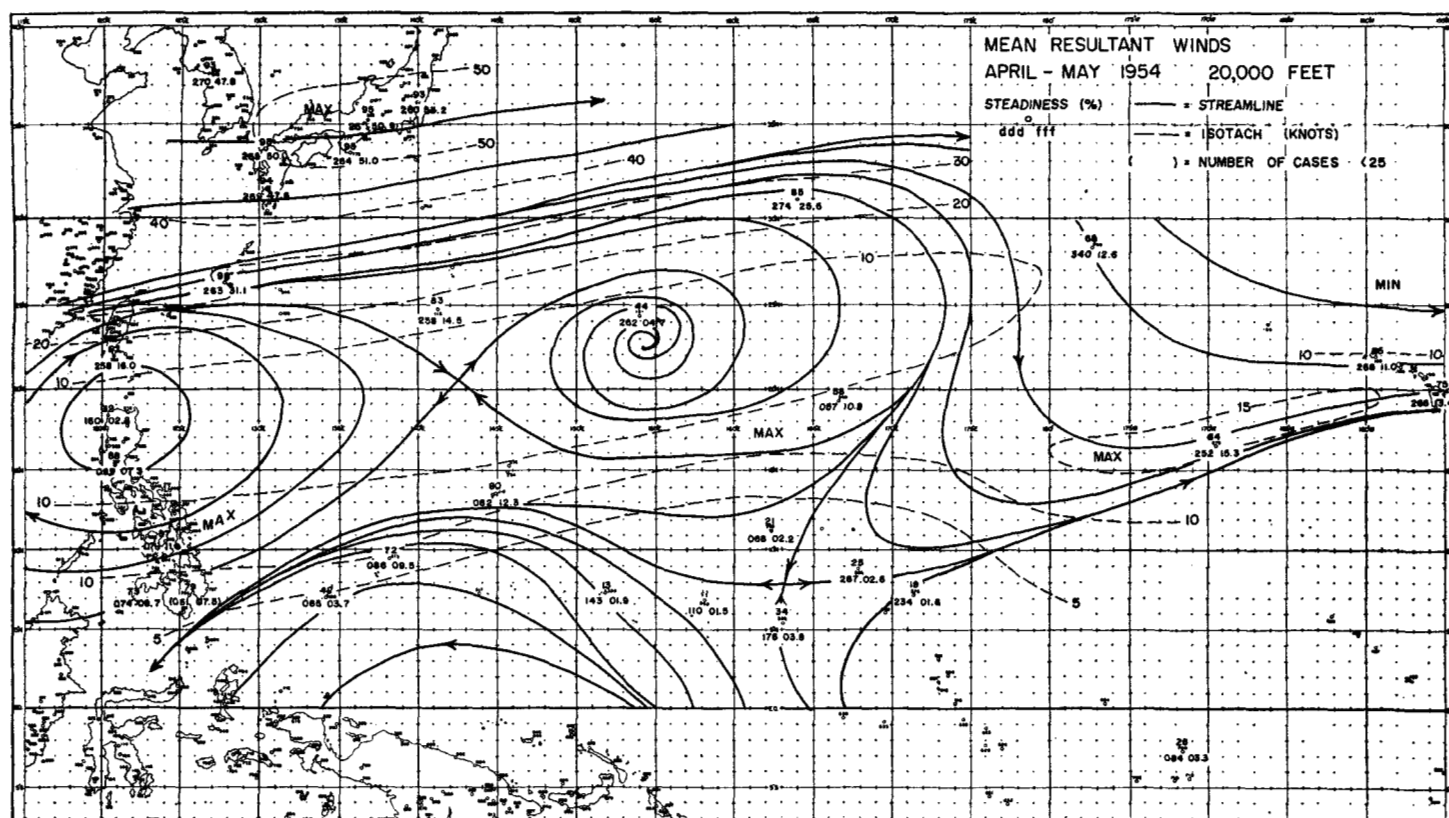


FIGURE 20.—The field of motion at 20,000 feet, April 16–May 15, 1954.

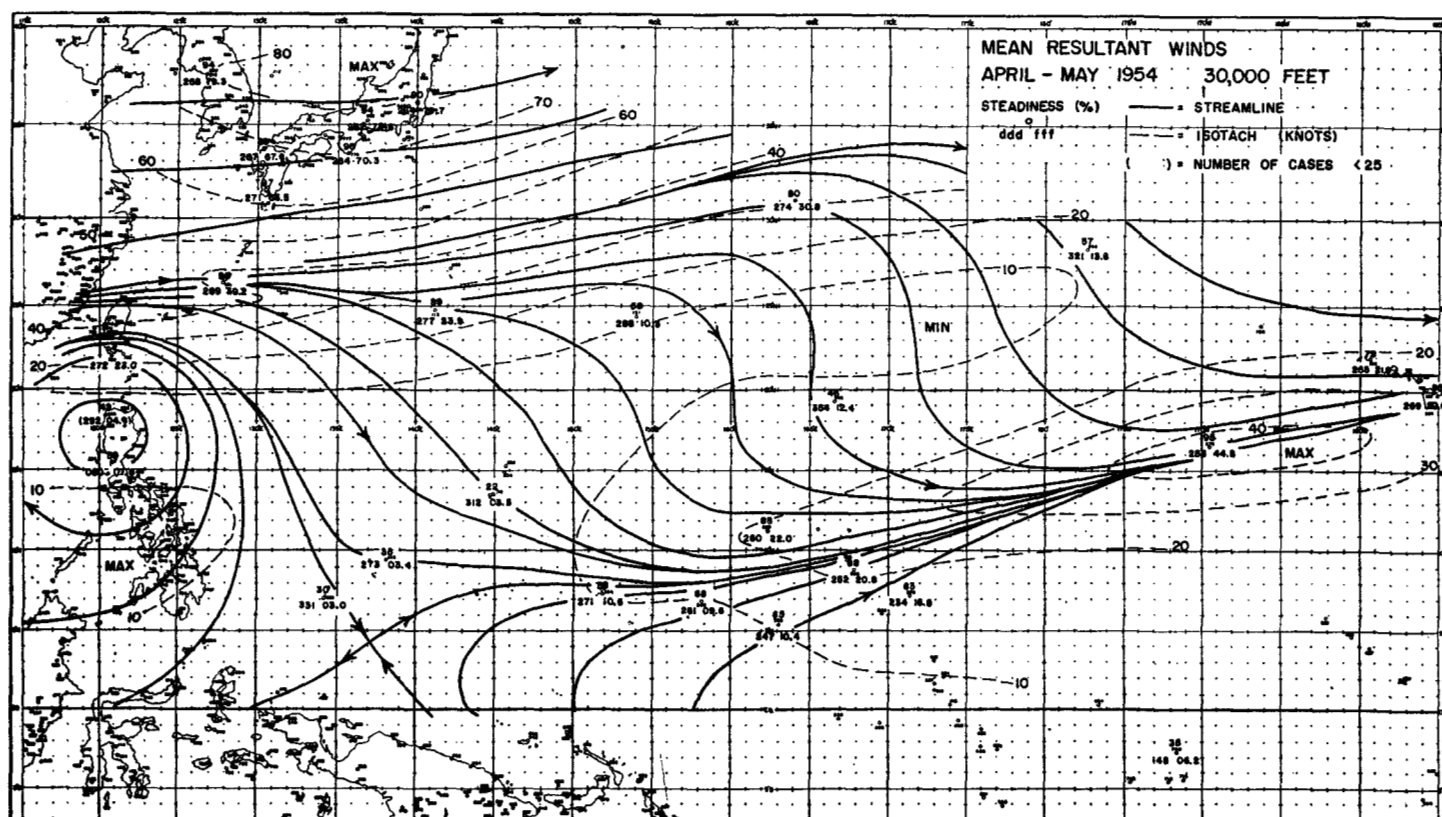


FIGURE 21.—The field of motion at 30,000 feet, April 16–May 15, 1954.

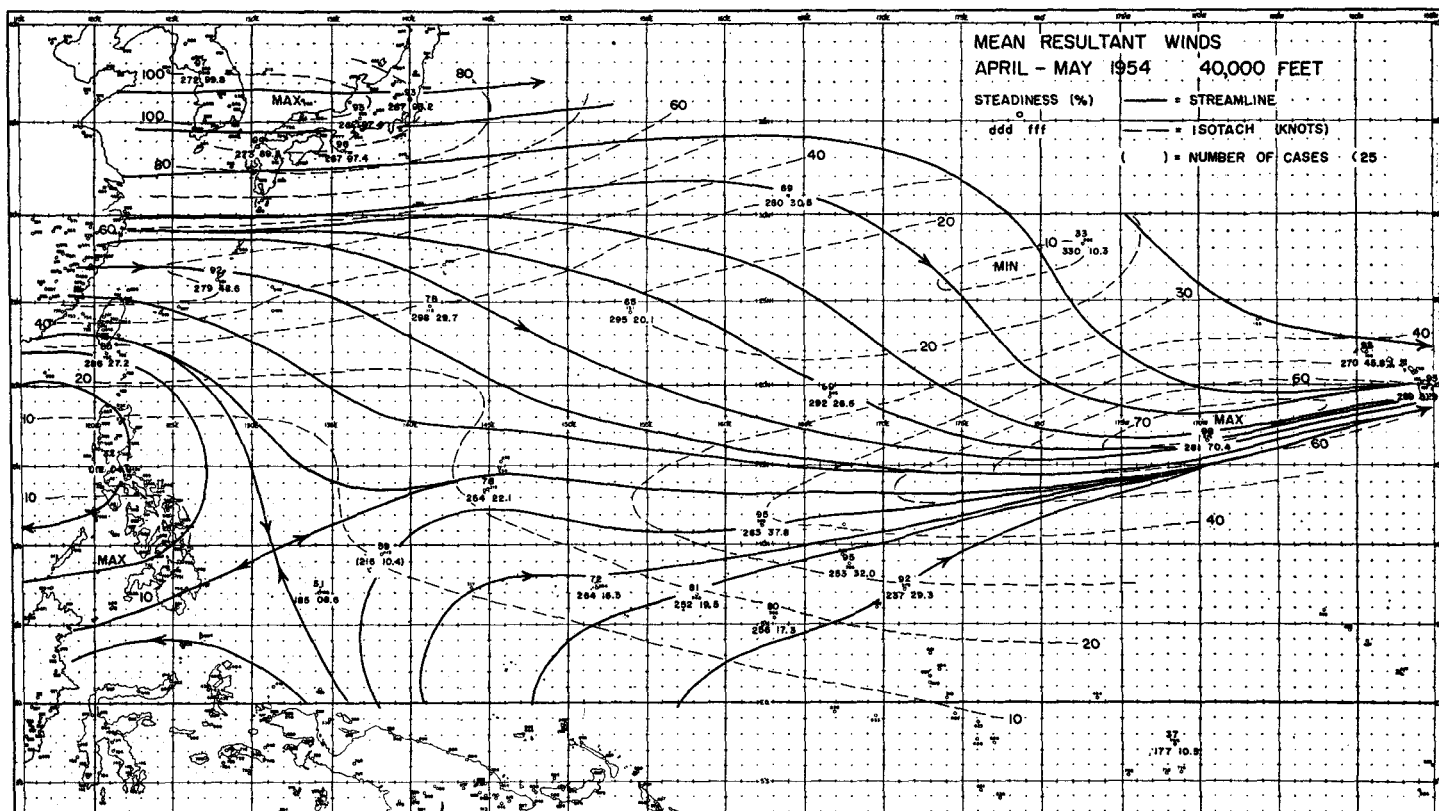


FIGURE 22.—The field of motion at 40,000 feet, April 16–May 15, 1954.

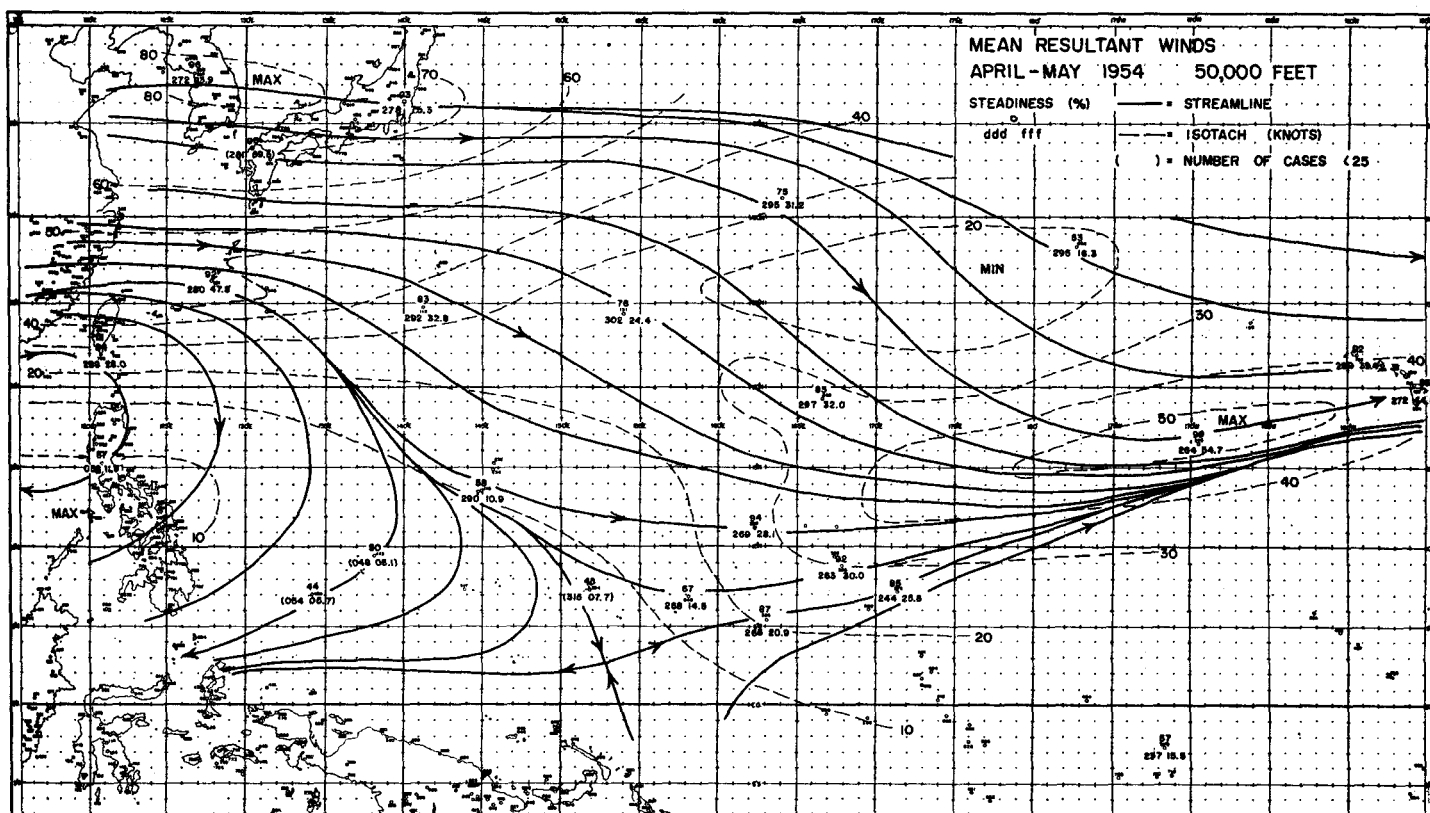


FIGURE 23.—The field of motion at 50,000 feet, April 16–May 15, 1954.

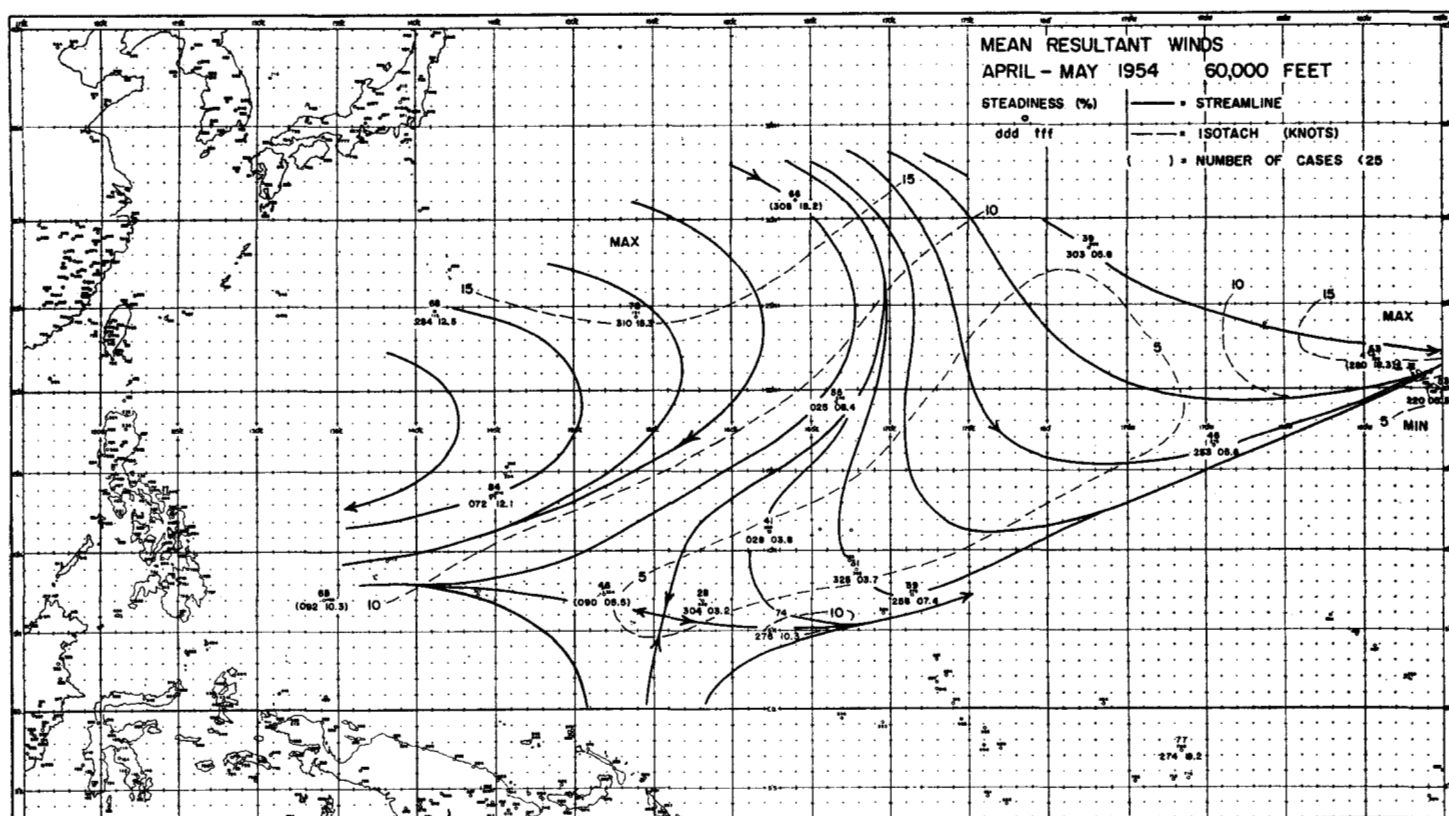


FIGURE 24.—The field of motion at 60,000 feet, April 16–May 15, 1954.

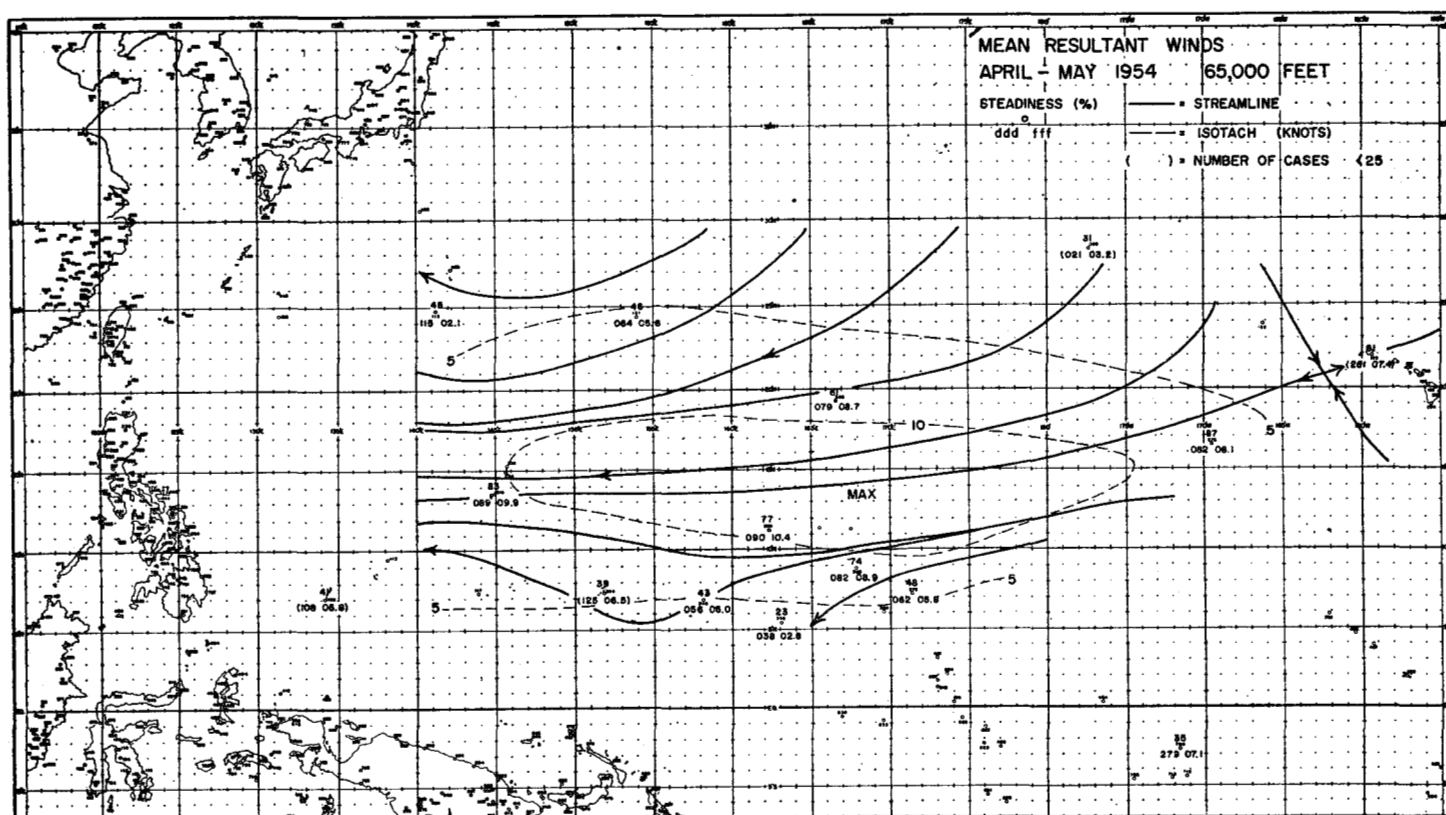


FIGURE 25.—The field of motion at 65,000 feet, April 16–May 15, 1954.

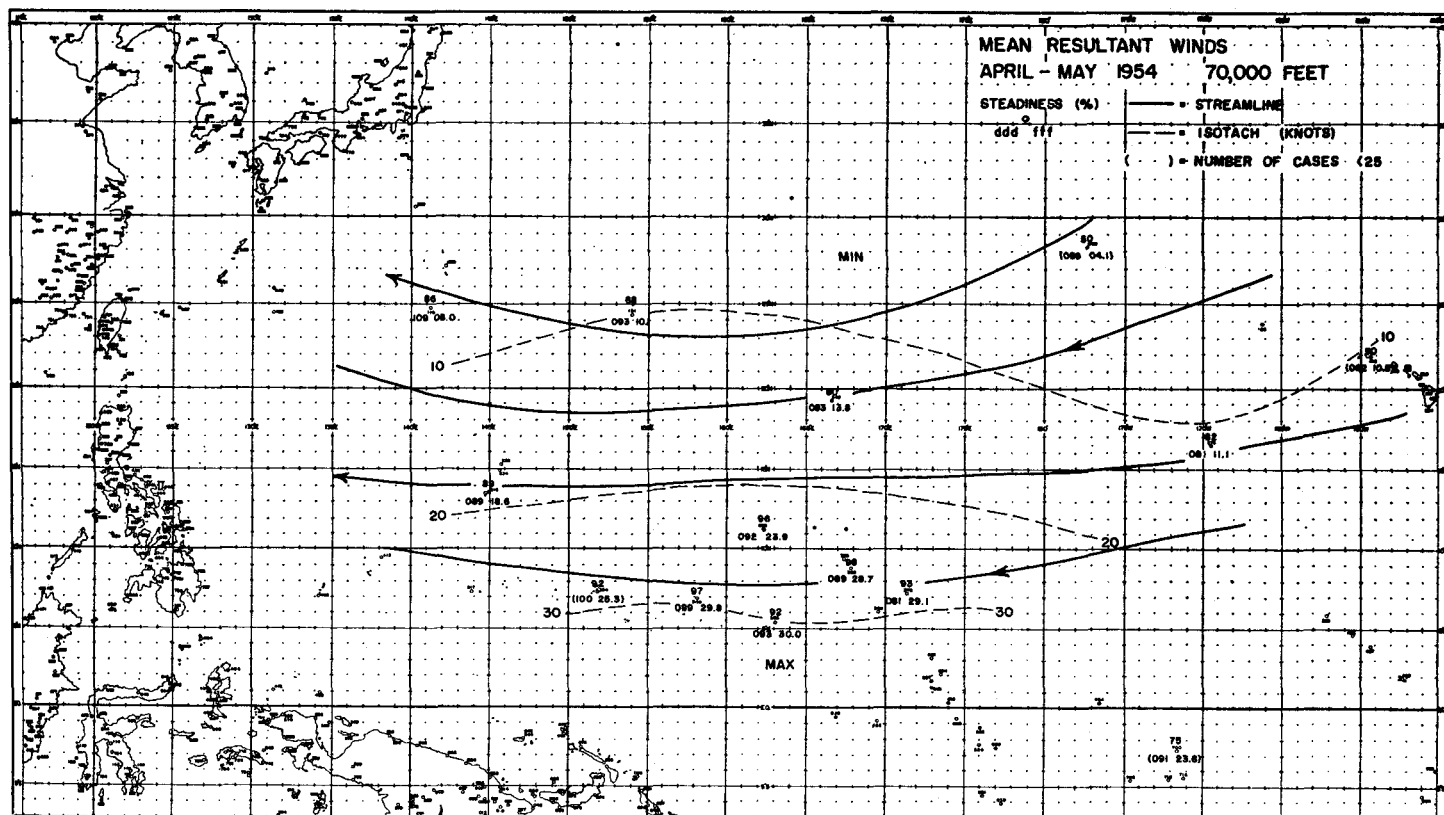


FIGURE 26.—The field of motion at 70,000 feet, April 16–May 15, 1954.

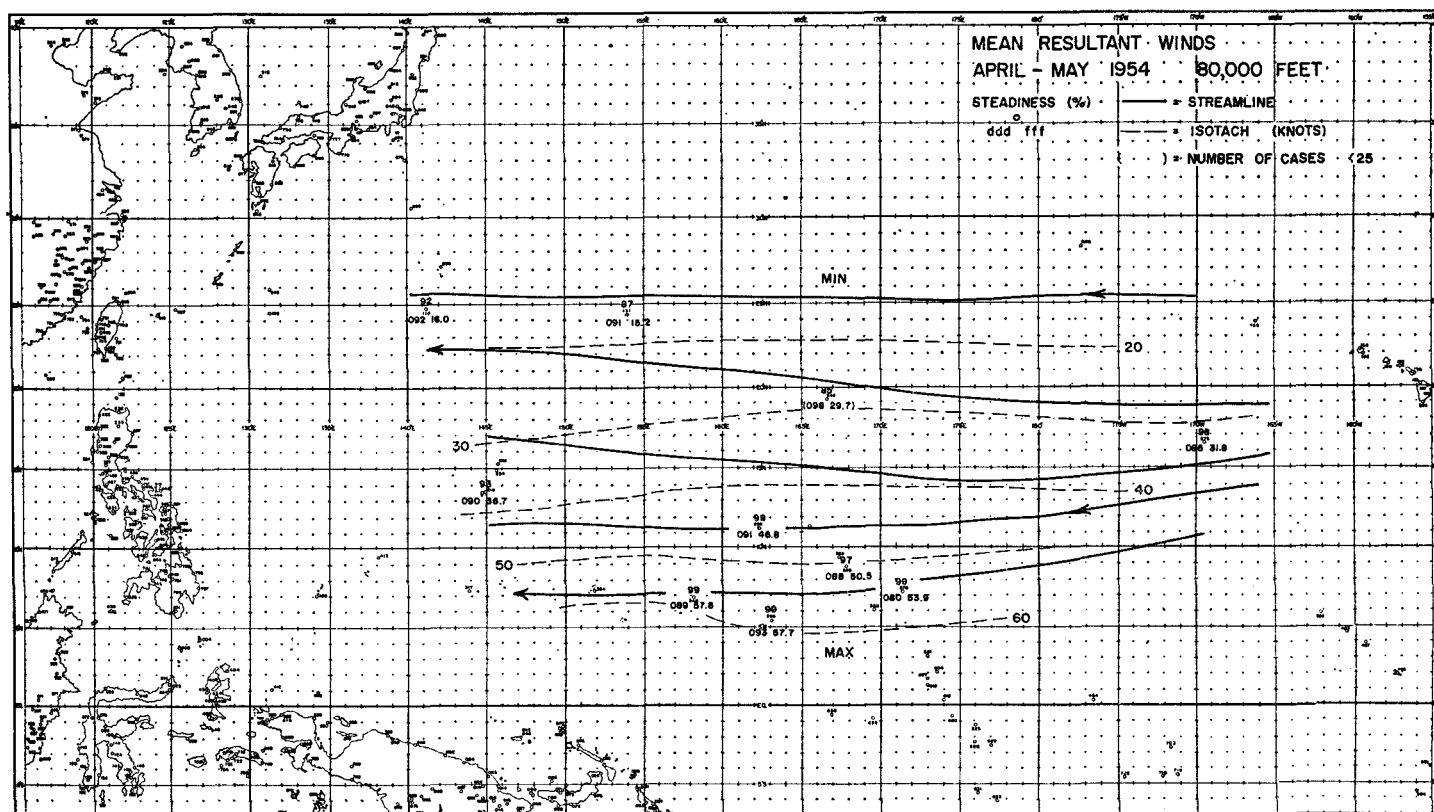


FIGURE 27.—The field of motion at 80,000 feet, April 16–May 15, 1954.

because they typify high- and low-index situations, as understood qualitatively by the synoptic meteorologist.

3. In the Central Pacific the wind steadiness associated with the upper tropospheric wind systems is greater than that associated with the lower tropospheric systems. This fact points up the large stability of these large-scale upper-level wind circulations in that area.

4. As far as the upper tropospheric and lower stratospheric circulations are concerned the maps are not incompatible with those already published (Kochanski [4], Flohn [5], U. S. Weather Bureau [6]). However, it should be pointed out that no attempt at the separation of "high-index" and "low-index" mean circulations was formerly made so that those analyses probably represent averages based on situations of both types.

5. There still remains the fundamental difficulty of describing in the three-dimensional picture, the relation of the circulation in the Northern Hemisphere to that of the Southern Hemisphere. This could be remedied if additional stations were instituted from 5° N. to 10° S. even for limited periods of time.

ACKNOWLEDGMENTS

The author wishes to thank Mr. Julius Korshover, Miss Rose Wakukawa, and Mrs. Susan Yang for their aid in preparing the resultant wind values.

REFERENCES

1. J. Korshover, "Mean Winds over the Marshall Islands," *Scientific Report* Nos. 1, 4, 6, 8, 10, Air Force Cambridge Research Center, Contract No. AF 19 (604)-546, 1954, and 1955.
2. C. E. Palmer et al., "The Practical Aspect of Tropical Meteorology," *Special Report* No. 2, Air Force Cambridge Research Center, Contract No. AF 19 (604)-546, 1955. (Also published as *Air Force Surveys in Geophysics*, No. 76, Atmospheric Analysis Laboratory, Air Force Cambridge Research Center, Bedford Mass., September 1955.)
3. C. E. Palmer, "The General Circulation Between 200 mb. and 10 mb. Over the Equatorial Pacific," *Weather*, vol. 9, No. 11, Nov. 1954, pp. 341-349.
4. A. Kochanski, "Cross Sections of the Mean Zonal Flow and Temperature along 80° W," *Journal of Meteorology*, vol. 12, No. 2, April 1955, pp. 95-106.
5. H. Flohn, "Die Planetarische Zirkulation der Atmosphäre bis 30 km Höhe," *Berichte des Deutsches Wetterdienstes in der U. S. Zone*, No. 12, 1950, pp. 156-161.
6. U. S. Weather Bureau, "Normal Weather Charts for the Northern Hemisphere," *Technical Paper* No. 21, Washington, D. C., 1952.